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BRL

A 1-MeV FLASH X-RAY SHAPED-CHARGE TEST FACILITY

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13. ABSTRACT *(Maximum 200 words)*

The Ballistic Research Laboratory has installed four channels of 1-MeV Hewlett Packard flash x-ray pulsers at Experimental Research Facility 16. ERF 16 is a shaped-charge research facility devoted to the study of the collapse, formation, and growth of jets from shaped-charge liners, as well as the interaction of shaped-charge jets with various target designs.

The 1-MeV test site uses ~~utilizes~~ both a blow-away film holder to study liner collapse and a 4.4-meter-long stationary film holder to observe the free flight of the jet and/or jet-target interactions. The great length of film available allows tip to slug (or tail) coverage of most shaped-charge warheads. The design and use of the film holders and the methodology used to locate the focal point of each of the 1-MeV flash x-ray pulsers are discussed in detail.

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1. INTRODUCTION

The Ballistic Research Laboratory's (BRL) Experimental Research Facility 16 (ERF 16) has recently developed and begun to utilize a new test facility. The facility features four 1-MeV flash x-ray pulser systems and improvements in both film holder design and film protection. The new test facility was constructed primarily to provide enhanced capabilities for the study of shaped-charge jets and the interaction of shaped-charge jets with various targets.

2. DESCRIPTION OF FILM HOLDERS

2.1 Blow-Away Film Holder. Figure 1 shows the new test facility. As shown, two film holders are used. The first film holder is termed a "blow-away," as it is allowed to move unconstrained when hit by the explosive blast. The blow-away holder is used to study shaped-charge liner collapse and jet formation. Several different holders are available, depending on individual test requirements. These film holders range in size from 356 mm x 432 mm to 356 mm x 1259 mm. The blow-away film holders are constructed of 150-mm-steel angle iron frames. The films are protected from the explosive blast and any fragments by 13 to 25 mm of aluminum plate and either 13 mm of foam rubber or 6 mm of wool felt. The film screen package is then backed with 13 mm of foam rubber or 6 mm of wool felt and 13 mm of aluminum to prevent flexing and breaking of the intensifying screens. The combination of film and protection is mounted in the angle iron frame and held in place, from the back, by 2 steel bars inserted through slots which are cut in the sides of the frame. For large warheads, a wedge-shaped shield is placed in front of the film holder to deflect the blast.

The wedge-shaped blast shield, used to protect the blow-away film cassette, is based on Boyce's wedge concept.* Figure 2 depicts a typical setup utilizing a blow-away cassette and a wedge shield. The shield utilizes a 30° half-angle to deflect the blast around the film holder. For uncased warheads, where fragment damage to the film is not a concern, the wedge typically is constructed of 13-mm plywood. For heavily confined warheads, the wedge shield may be constructed of polycarbonate, polyethylene, or glass-reinforced plastic, depending on the mass and the velocity of the fragments expected. Currently, Paxton is studying the use of a molded foam wedge as a blast deflector

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* Boyce, G.L. "Wedges Used for Film Cassette Protection." BRL-MR-3454, U.S. Army Ballistic Research Laboratory, Aberdeen Proving Grounds, Aberdeen, MD, July 1985.

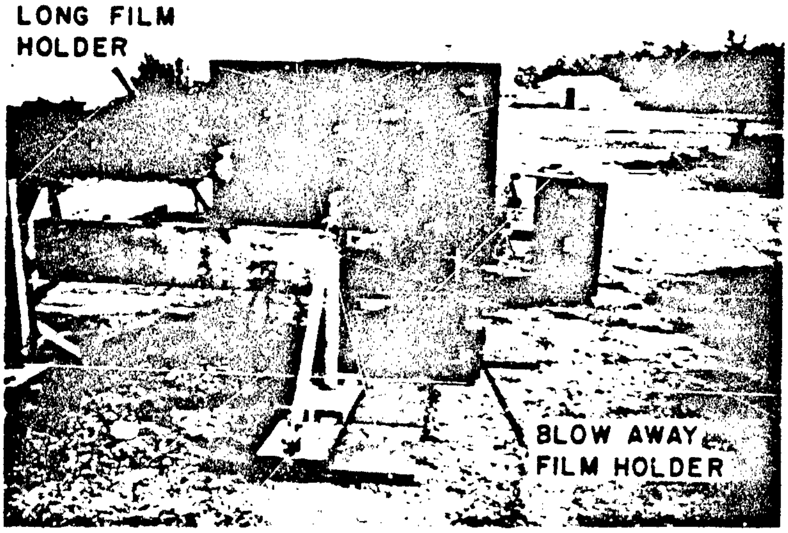

Figure 1. New 1-MeV Test Site.

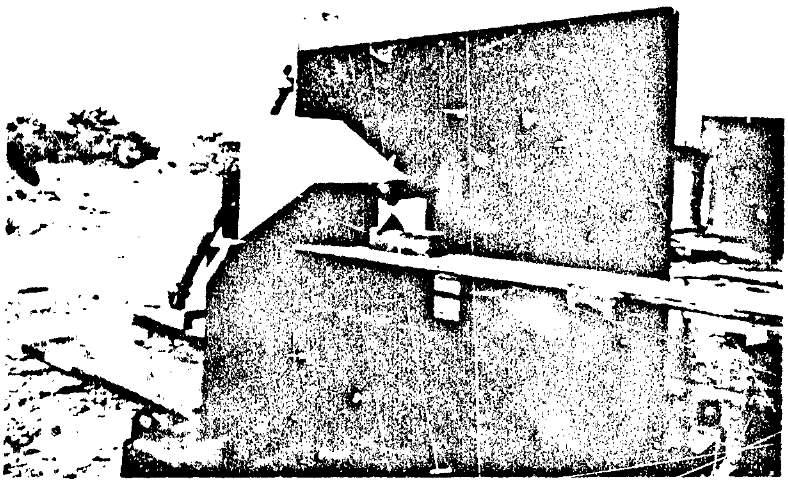

Figure 2. Typical Test Setup.

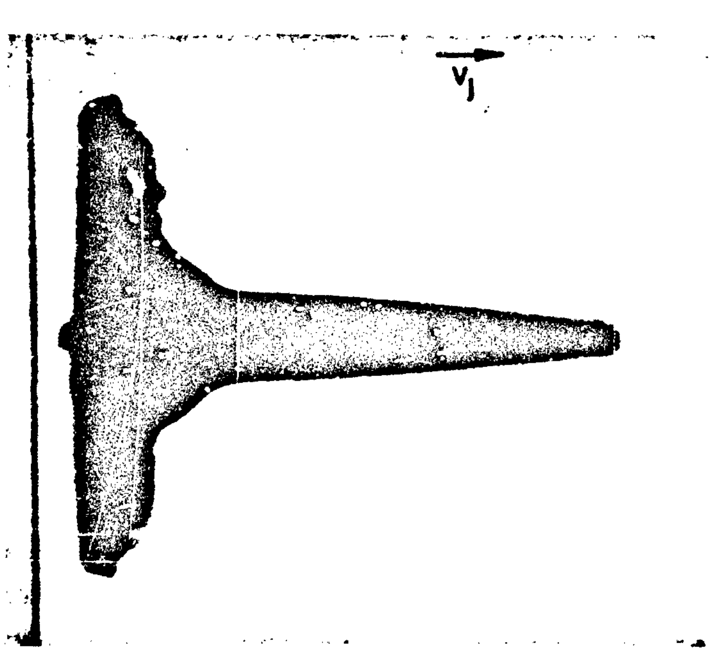

Figure 3. Hemispherical Liner Collapse.

for non-cased warheads, which will also be compatible with lower intensity x-ray sources. Figure 3 is a sample radiograph of the collapse of a 76-mm diameter, copper, hemispherical shaped-charge liner taken 40 μsec after detonation. Figure 3 was obtained using the blow-away film holder with a wedge-shaped, plywood shield.

2.2 Long Film Holder. The long film holder is 4.3 meters long and holds 2 rows of 10, 356 mm x 432 mm sheets of film. This permits viewing shaped-charge jets at long delay times and, in many cases, makes possible the viewing of the entire jet from the tip to the slug (tail). This increases the accuracy of the measurement of the breakup time and of the mass distribution of the jet.

The construction of the long film holder is shown in Figure 4 together with its innovative support system. A pedestal ball-and-socket supports one end of the holder while three turnbuckles support the other end. The top turnbuckle serves to level the holder. The bottom two turnbuckles serve to adjust the holder to a vertical position and parallel to the line of the tubeheads.

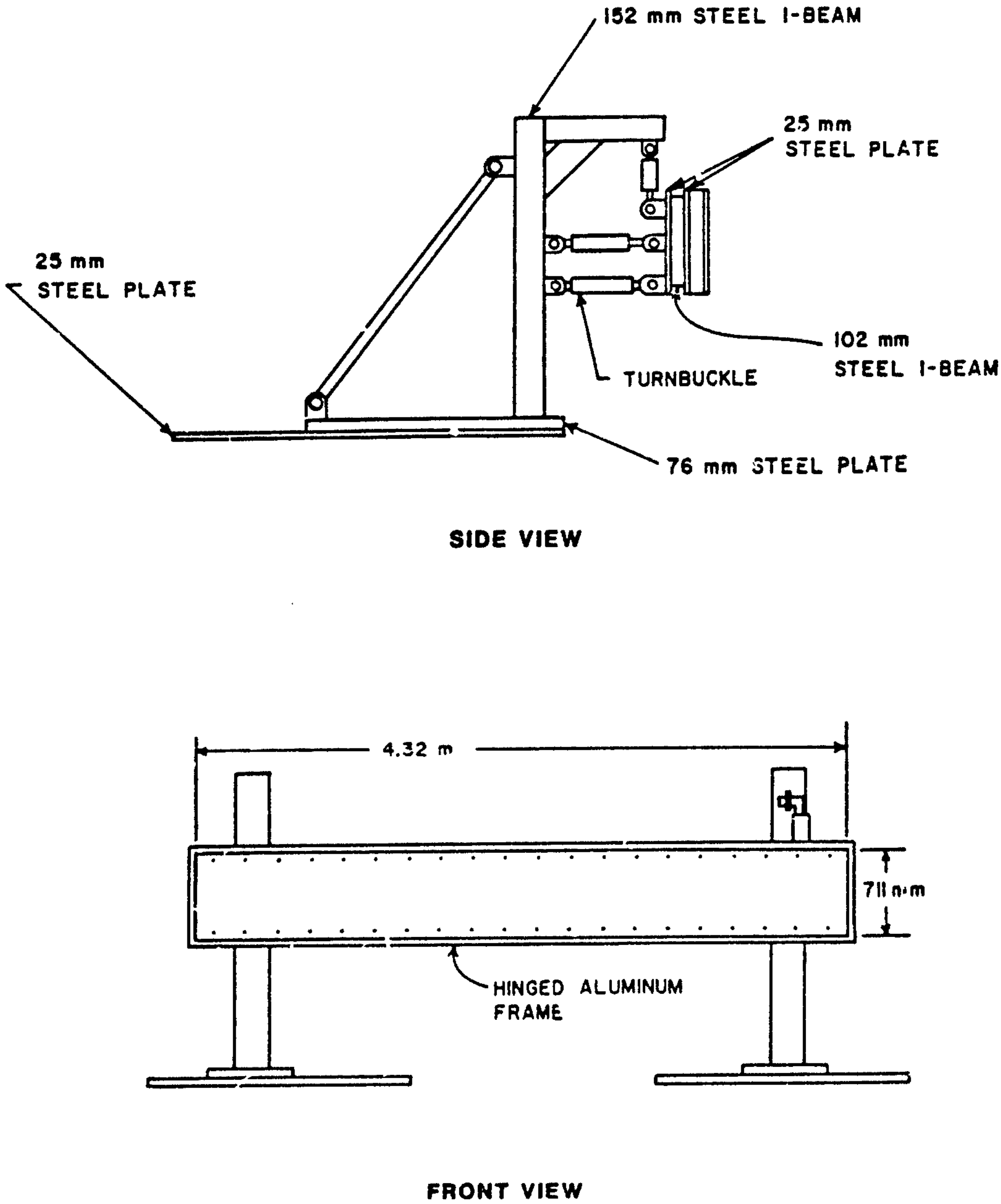

Figure 4. Long Film Holder.

The flexibility of adjustment afforded by this arrangement facilitates the fine adjustment of the position and the alignment of the holder and speeds this operation. In the future, the two lower turnbuckles will be replaced by hydraulic jacks making the alignment procedure easier still.

The films are protected from fragments and blast by a 6.4-mm aluminum sheet, followed by 6.4 mm of wool felt. The aluminum cover sheet has 6.4-mm holes located 76 mm from the top and bottom edges of the frame. The holes are spaced 216 mm apart and serve as fiducials for data reduction. The films and intensifying screens are placed in envelopes made by Detek Corporation, Temple Hills, MD. The envelopes measure 356 mm x 2,159 mm and are mounted on 6.4-mm Masonite. The Detek envelopes are light-proof and allow the films to be removed from the film holder in full daylight. The envelopes are backed by 6.4 mm of wool felt mounted on 13 mm of plywood.

3. X-RAY TUBE LOCATIONS

The films in the long film holder are exposed by tubes 2, 3, and 4 (Figure 5). However, in order to reduce the time and effort required to prepare for a test, only the focal point of tube 2 is marked with a fiducial on the film. The focal points of the other two tubes are determined from the measured spacing between the tubes. The focal point of tube 2 is determined using a transit with a laser mounted on top (Figure 6). The laser-transit system is placed in close proximity to the location of the focal point and at the same distance from the film as the jet path. The laser-transit system is then turned until the laser beam is parallel to the film plane and coincident with the shotline. Next, the laser is turned 90° in the direction of the x-ray tube, and the distance from the x-ray source to the laser dot is measured. The laser is then rotated 180°, and the focal point is marked on the film with a thin steel bar.

The locations of tubes 3 and 4 are determined relative to tube 2 and the film plane using a transit. The transit is placed between the film holder and the x-ray tubes in a position such that tubes 2, 3, and 4 may be viewed with the transit. A Cartesian coordinate system is established with origin at the center of the transit (Figure 7). The x-axis is horizontal and parallel to the film plane. The y-axis is horizontal, perpendicular to the film plane, and positive in the direction of the tubes. The z-axis is vertical and positive upward. Three measurements are taken for each tube. First, the distance from the center of the pulser face to the transit, D, is measured. Next, the angle between the positive x-axis

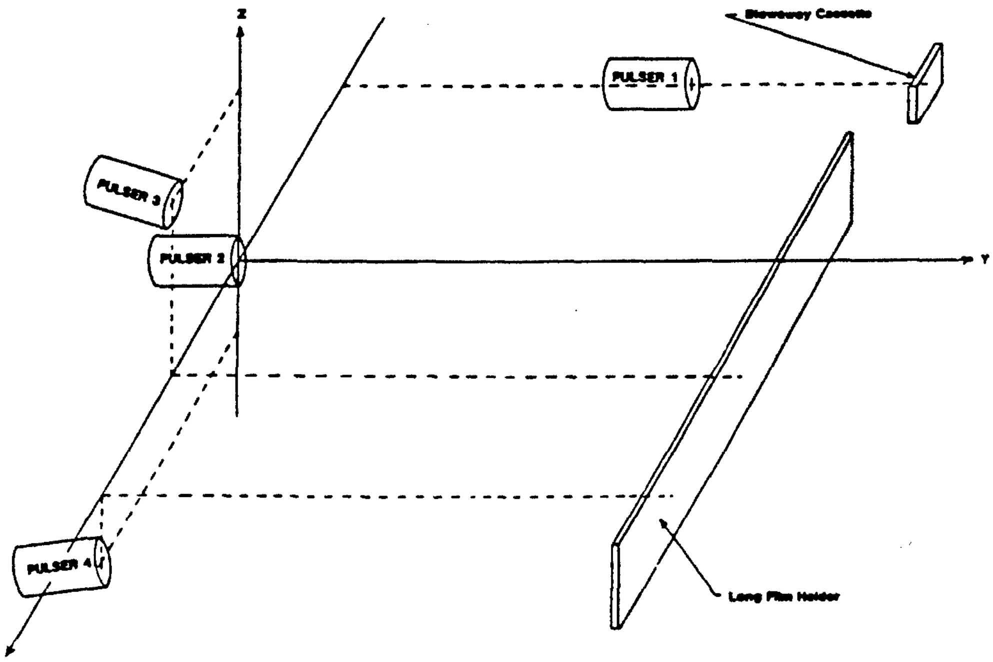

Figure 5. Tube Arrangement.

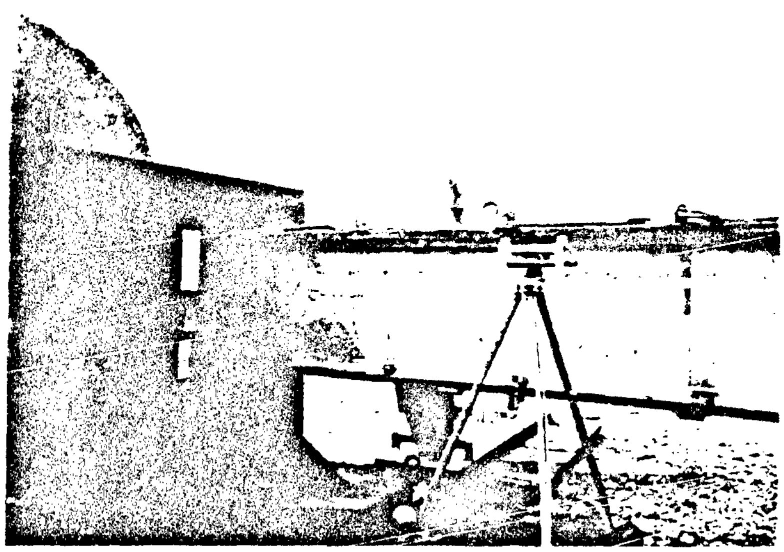

Figure 6. Laser-Transit System.

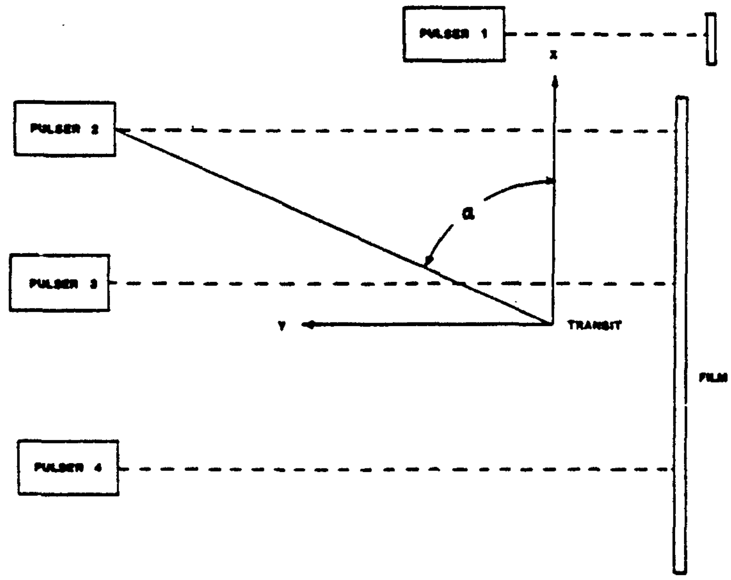

Figure 7. Top View of 1-MeV Site.

and the line from the origin to the center of the pulser face (Figure 7), α, is recorded. Finally, the angle between the horizontal and the line from the center of the pulser face (Figure 8), γ, is measured. The coordinates at the center of each pulser face are given by

$$x_i = (D_i \cos(\gamma_i)) \cos(\alpha_i) \tag{1}$$
$$y_i = (D_i \cos(\gamma_i)) \sin(\alpha_i) \tag{2}$$
$$z_i = D_i \sin(\gamma_i). \tag{3}$$

The x and y axes are then rotated 180° and translated to the center of the face of pulser 2 such that

$$x_i = (-1)(x_i - x_2) \tag{4}$$
$$y_i = (-1)(y_i - y_2) \tag{5}$$
$$z_i = z_i - z_2, \tag{6}$$

where the subscripts refer to the pulser number. This gives the coordinates at the center of each pulser face relative to pulser 2. A further coordinate translation is then required to determine the relative

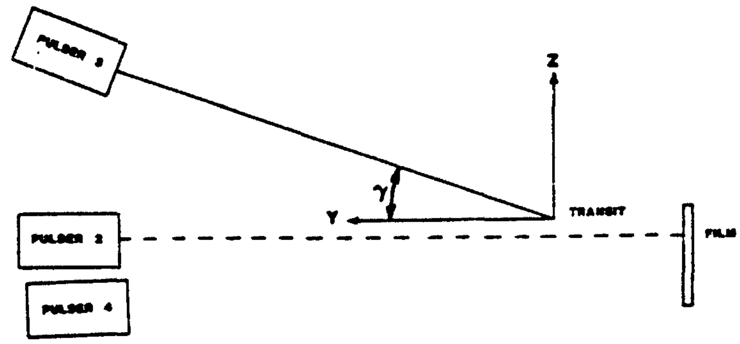

Figure 8. Side View of 1-MeV Site.

position of the x-ray source for each tube. The x and z coordinates are used to determine the focal points of tubes 3 and 4, and the y coordinates are used to calculate magnification factors.

For small shaped charges (under 5 lb of explosive), the long film holder allows the entire shaped-charge jet from tip to slug to be recorded and characterized. This capability is demonstrated by a series of radiographs (shown in Figure 9) obtained at the 1-MeV site. Figure 9 shows a 76-mm diameter, copper hemispherical shaped-charge liner both during the collapse process and after it has formed a jet. The pole of the liner has been removed and replaced with a solid hemispherical plug which is clearly visible at the tail of the jet. For larger shaped-charge warheads (5-15 lb), a blast wall, shown in Figure 1, is used to protect the long film holder. Film coverage for large warheads is provided by both the blow-away cassette and the long film holder. The great length of film coverage allows such quantities as jet breakup time, virtual origin location, and the liner mass distribution to be determined with greater accuracy.

4. SUMMARY

Innovative features of the new 1-MeV flash x-ray test facility provide increased capabilities for the study of shaped-charge liner collapse and jet characteristics. The blow-away film holder and wedge blast-shield enable liner collapse studies of shaped charges containing up to 15 lb of explosive. The long film holder often makes possible the viewing of the entire jet from the tip to the slug increasing the accuracy of breakup time and mass distribution measurements. The ball-and-socket and turnbuckle holder support system permits the precise adjustment of the position and alignment of the film holder.

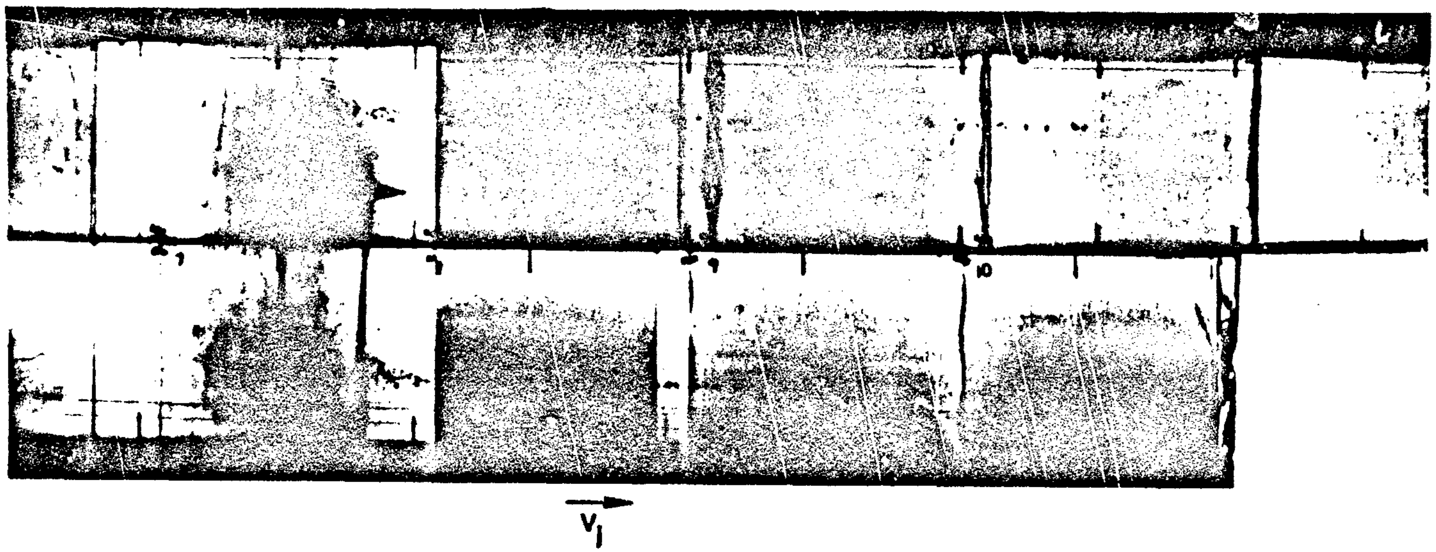

Figure 9. <u>Free-Flight of a Shaped-Charge Jet.</u>

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